ENRICHING GENE POOL TO ENHANCE RICE PRODUCTIVITY UNDER SUBMERGENCE AND MEDIUM STAGNANT WATER STRESSES IN MEKONG DELTA

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ABSTRACT

Materials from the result of first years of yield trial under submergence and medium stagnant water stresses were selected for conducting our experiment. The preliminary results of 20 rice accessions were reported in MYT in Winter-Spring seasons (2011-2012) under submergence and medium stagnant water stresses. Subsequently, on-farm participatory varieties selection (PVS) trials were conducted at five different sites in An Giang, Hau Giang and Can Tho using promising lines from MYT. Mostly the genotypes were short growth duration of 90-105 days. At maturity, farmers at each location as well as researchers voted the best breeding lines. Discussions were emphasized on high yielding, BPH, blast resistance, good grain quality and water stress tolerance. Moreover, more crosses were continued to develop using rice landraces as important breeding materials to have new rice genotypes with good grain quality properties and high yield. They must adapt to submergence condition in Mekong Delta.

Keywords: *AMMI (additive main effects and multiplicative interaction), medium stagnant, submergence.*

INTRODUCTION

Submergence is a serious problem affecting rice production in flood prone areas worldwide. In addition, climate change is further aggravating flooding risks of *rainfed* lowland rice areas, especially in areas belongs to Mekong Delta. Submergence can be caused by river overflows, excessive rain and/or tidal inundation (Sairam *et al*., 2008). Submergence tolerant lines with high yield potential were obtained in the early 1990s (Mackill *et al*., 1993). However, these tolerant prototypes are never widely adopted by farmers since they were inferior in grain quality or in other traits needed for local adaptation. On the other hand, mega varieties that possessed most traits desired by farmers but are submergence intolerant begin to spread widely in both irrigated and *rainfed* lowland areas of south and south-east Asia (Mackill *et al*., 2006). To ensure the adoption of the final breeding product by the farmers, some varieties with submergence tolerance are successfully developed. Food security crops need to be climate proofed to combat the challenges posed by climate change and variability. The overall objective of this report is to develop new high yielding varieties for low input cultivation in a range of agro-ecological zones by broadening adaptability. The specific objectives are: (i) to explore rice germplasm and identify high yielding genotypes under submergence and medium stagnant water stresses, (ii) to enrich rice gene pool, share genetic resources and knowledge and foster networks between participating research groups and potential end-users for their varieties.

MATERIALS & METHODS

20 rice genotypes with submergence tolerance and high yielding were tested with two standard checks plus farmer's varieties (Table 1) under naturally occurring submergence conditions.

Field trials

Five experiments were laid out in RBD with three replications at Tri Ton, Thoai Son (An Giang province), Vi Thuy (Hau Giang) and Truong Xuan, Thoi Lai (Can Tho). In the first experiment, 20 varieties were established to test submergence tolerance within triple-rice crop system. The seedlings were transplanted with the spacing of 20 x 20 cm. The fertilizer formula was 100-60-40 kg N-P_2O_5-K_2O/ha. Weed control was done by applying a post-emergence herbicide.

Trait evaluations

Eight agronomic traits were assessed as days to heading, plant height, panicle length, panicle number per plant, unfilled grain percentage, filled grains per panicle, 1,000-grain weight and grain yield (5 m^2 / plot).

GxE interaction analysis was done by Eberthart and Russel's model (1966).

$$Yij = \mu i + \beta Ij + \delta ij$$

with Ij = $\left(\sum Yij / V\right) - \left(\sum \sum Yij / vn\right)$

where

Y_{ij}: the mean performance of i^{th} genotype in j environment

μ_i: general mean of i th genotype

β_{ij}: deviation from regression of i^{th} genotype in the j th environment

I_j: the environment index, which is defined as deviation of mean of all genotypes at a given environment from the over all mean

RESULTS & DISCUSSION

2011 Wet season at An Giang

The most rice varieties were found to resist to brown plant hopper and leaf blast disease. However, there was some rice varieties affected with yellow stunt disease. The growth duration showed little variation (from 90-100 days) which is classified as short growth duration group. At the stage of 20 days after transplanting (DAT) the rice variety with the maximum height was OM4900 (46.67 cm), and the minimum was OM10000 (40.67 cm). In the period of 35 DAT, there was large difference between tested varieties, OM8927 variety had maximum height (91.33 cm) and minimum height (68 cm) in OM70L

Table 1. Yield and yield components at Ta Danh – Tri Ton (2011-2012 Winter-Spring)

No.	Entry	Tillers / hill	Pan. length (cm)	Filled grains /pan.	Filled grain (%)	1,000 gr wgt (g)	Yield (t/ha)	Pl Height (cm)
1	IR64-Sub1	14a	24.23cd	146b-e	89.4ab	28.14d	8.1cd	102.33
2	OM10000	12ab	23.07de	149b-e	91.23ab	24.53f	7.77de	102.00
3	TLR346	11ab	21.77e	115e	95.35a	29.29b	8.33cd	94.67
4	OM8927	10ab	23.67cde	125cde	84.4abc	32.37a	6.73g	123.00
5	OM8928	14a	23.3de	120de	89.58ab	28.76c	10.77a	101.67
6	OM8108	12ab	23.77cd	141b-e	89.26ab	28.62c	8cd	107.67
7	OM8104	9ab	28.6a	186a	88.67ab	27.92d	9.83b	106.00
8	MNR5	8b	22.83de	147b-e	82.26bc	28.48c	8.77c	104.00
9	OM7347	8b	23.87cd	175ab	94.1ab	27.85d	8.17cd	100.67
10	OM70L	11ab	24.67cd	129cde	95.83a	29.22b	6.83fg	99.67
11	OM10041	12ab	27.17ab	158a-d	76.28c	27.4e	7.6def	102.00
12	OM10040	12ab	25.5bc	144b-e	90.24ab	29.38b	7.53d-g	101.67
13	OM4900	9ab	23.17de	163abc	93.51ab	27.44e	7.47d-g	107.00
14	TLR347	12ab	26.93ab	121de	91.34ab	20.58g	7efg	96.33

In a column, means followed by the same letter (s) are not significantly different at 5% level

Two rice varieties obtained the highest tiller number (14 tillers/hill) were OM8928 and IR64-Sub1. Under controlled submergence condition, the highest yielding varieties were OM8928 (10.77 tons/ha) and OM8104 (9.83 tons/ha) while OM8927 offered the lowest. Survival percentage was uniformly high (>99%) among all varieties.

Table 2. Yield and yield components at Thoai Son (2011-2012 Winter-Spring)

No.	Entry	Tillers / hill	Pan. length (cm)	Filled grains /pan.	Filled grain (%)	1,000 gr wgt (g)	Yield (t/ha)	Pl Height (cm)
1	IR64-Sub1	10ab	22.57cd	90c	69.92def	28.14e	8.1bcd	103.33
2	OM10000	10ab	22.5cd	87c	63.8fg	24.45i	8.2bc	104.00
3	TLR346	10ab	19.33e	88c	96.62a	29.26c	8.77b	95.67
4	OM8927	10ab	24bcd	103c	68.44ef	32.31a	8.3bc	118.00
5	OM8928	9b	22.73cd	137b	92.98a	28.71d	10.77a	110.67
6	OM8108	12a	24.33bc	109c	60.94fg	28.69d	8.37bc	113.00
7	OM8104	9ab	23.5bcd	104c	78.32cd	27.95ef	8.7b	106.67
8	MNR5	11ab	23.73bcd	99c	68.16ef	27.66gh	8.47b	101.33
9	OM7347	9b	22.97cd	92c	58.44g	27.86fg	8.7b	99.00
10	OM70L	12a	25.17b	223a	88.12ab	29.25c	8.27bc	97.67
11	OM10041	12a	22.17d	99c	74.18cde	27.57h	7.6cde	105.67
12	OM10040	10ab	20.03e	91c	74.65cde	29.58b	7.43de	101.33
13	OM4900	8b	27a	149b	79.64bc	27.57h	6.9e	111.00
14	TLR347	11ab	24.13bcd	89c	88.16ab	20.62j	8.33bc	95.33

In a column, means followed by the same letter(s) are not significantly different at 5% level

The data in table 2 indicated that OM8108 and OM10041 offered the highest tiller number (12 tillers/hill) while OM4900 was the lowest (8 tillers/hill). Under controlled submergence condition, the highest yielding varieties were OM8928 (10.77 tons/ha) and TRL346 (8.77 tons/ha), while OM4900 was the lowest.

2011 Wet season 2011 at Hau Giang

Table 3. Yield and yield components at Vi Dong-Vi Thuy (2011-2012 Winter-Spring Season)

No.	Entry	Pan. / hill	Panicle length (cm)	Filled grains / panicle	Unfilled grain (%)	1,000 gr wgt (g)	Yield (t/ha)
1	OM10041	10.2a-c	23.8ab	140.1b-d	15.5ab	27.9f	8.60a-c
2	Can Tho 2	9.6bc	23.4b	149.8ab	10.8ab	28.6d	9.00ab
3	Can Tho 3	9.3b-d	24.8ab	141.2b-d	13.8ab	29.5b	9.10ab
4	OM7347 (CanTho 1)	10.1a-c	24.6ab	150.0ab	11.8ab	29.1c	9.80a
5	OM4488	8.7cd	24.2ab	145.1bc	10.5ab	27.2g	7.40cd
6	OM8108	10.1a-c	25.3a	138.1b-d	14.7ab	28.1e	9.60a
7	OM8928	7.9d	23.4b	120.7de	10.4ab	26.7i	7.80b-d
8	OM70L	9.8a-c	24.2ab	127.6b-d	11.6ab	28.2e	6.30d
9	OM6L	10.4ab	25.4a	124.1cd	10.9ab	27.0h	9.40a
10	OM7L	9.8a-c	20.7c	99.1e	16.8a	23.6j	9.60a
11	OM4900 (check)	11.2a	24.0ab	135.8b-d	13.7ab	30.1a	9.80a
12	HG2 (OM6161)	9.9a-c	24.5ab	173.4a	8.0b	28.7d	10.00a
	CV%	9.9	4.51	10.2	37.8	0.3	10.1

In a column, means followed by the same letter(s) are not significantly different at 5% level

At Vi Dong- Vi Thuy (Hau Giang), the most serious problems are brown plant hopper and rice blast disease. However, results showed that most varieties were not affected by them, except OM8928 was sensitive to blast disease. Almost varieties in the trial were very slightly infected by yellow stunt virus disease. The growth duration varied from 85 to 100 days under triple-rice cropping system condition at Vi Thuy. Two varieties OM4488, OM10041 exhibited very short duration of 85 days. OM8108 expressed in the highest plant height (110.8 cm), and OM8928 as the shortest (94.7 cm).

2011-2012 Dry season in Can Tho

Little variation on growth duration was noticed in Can Tho site (95-105 days). They well adapted to the triple-rice season system there. OM6L obtained the highest grain yield (8.2 ton/ha) following by Can Tho 2 (7.5ton/ha), OM8928 and OM10041 (7.2t/ha), while Can Tho 3 was the lowest.

Table 4. Yield and yield components at Truong Xuan A, Thoi Lai

No.	Entry	Pan. / hill	Panicle length (cm)	Filled grains / panicle	Unfilled grain (%)	1,000 Gr Wgt (g)	Yield (t/ha)
1	OM10041	12.3a	22.6a	122.3abcd	79.5abc	26.6d	7.20bc
2	Can Tho 2	13.3a	22.5a	130.6abc	69.9cd	26.4d	7.50ab
3	Can Tho 3	11.6a	23.1a	93.3d	70.7bcd	26.6d	5.90e
4	Can Tho 1	10.6a	21.6a	111.6bcd	72.1bcd	26.6d	6.70bcde
5	OM4488	11.0a	24.0a	109.6bcd	89.4a	26.8cd	6.90bcd
6	OM8108	12.6a	22.4a	111.3bcd	73.8bcd	25.7e	6.60bcde
7	OM8928	16.6a	22.9a	132.6abc	90.4a	27.2bc	7.20bc
8	OM70L	17.6a	22.5a	104.6cd	66.1d	27.3b	6.10de
9	OM6L	16.6a	24.1a	137.3ab	87.2a	27.4b	8.20a
10	OM7L	17.0a	22.3a	134.0abc	79.5abc	26.5d	6.40cde
11	OM4900	15.0a	23.6a	144.0a	83.8ab	28.2a	6.80bcde
CV%		28.0	6.5	17.2	13.0	2.6	10.9

In a column, means followed by the same letter(s) are not significantly different at 5% level

Table 5. Yield and yield components at Thoi Tan, Thoi Lai

No.	Entry	Pan. / hill	Panicle length (cm)	Filled grains / panicle	Unfilled grain (%)	1,000 gr wgt (g)	Yield (t/ha)
1	OM10041	16.3a	25.16a	149.67ab	81.80ab	26.64cdef	6.00a
2	Can Tho 2	16.6a	21.76bc	145ab	82.67ab	26.36ef	5.60ab
3	Can Tho 3	10.3b	23.6abc	108.67c	71.93b	26.79bcdef	5.00b
4	Can Tho 1	16.0a	21.6c	129abc	78.64ab	27.01bcde	6.20a
5	OM4488	15.3a	21.9bc	143.33ab	84.87a	27.07bcd	6.10a
6	OM8108	13.0ab	22.1bc	121bc	81.38ab	26.23f	5.50ab
7	OM8928	15.0ab	22.1bc	122bc	88.13a	27.32abc	5.6ab
8	OM70L	12.66ab	23.8ab	103.33c	78.65ab	27.44ab	5.60ab
9	OM6L	14.6ab	23.7ab	118.67bc	87.71a	27.4ab	5.80ab
10	OM7L	13.0ab	22.7bc	128.67abc	83.66a	26.39def	5.00b
11	OM4900	13.0ab	22.8bc	157.33a	76.68ab	27.92a	5.40ab
	CV%	20.1	6.2	16.90	8.30	2.30	9.90

In a column, means followed by the same letter(s) are not significantly different at 5% level

The low level of water affected this season and facilitated high yielding almost varieties. Low yield was recorded at Thoi Lai (Can tho) due to more serious stress as compared to other sites.

There was significant difference in grain yield between submergence and medium stagnant water stresses. Increasing the number of spikelets per panicle could be a primary target of breeding high-yielding rice varieties for submergence.

AMMI analysis

AMMI (Additive Main effects and Multiplicative Interaction) with new information for cultivars, environmental stratification and cultivar x environment interaction was addressed by (Miranda *et al.*, 2009). To identify cultivars with greater adaptability and stability has been widely used to offer promising genotypes for this purpose (Miranda *et al.*, 1998, Grunvald *et al.*, 2008). To ensure this, six Indica rice varieties were tested at 5 different locations in 2011-2012 Winter- spring seasons. Each site was designed into randomized complete block with three replications. Agronomical traits are presented in Table 12. The experiment was conducted in 3 provinces: Can Tho, An Giang and Hau Giang. The data show that OM4900 variety obtained the highest grain yield all these 5 sites. Most of the varieties showed good stability index. An understanding of GxE interaction is important at all stages of plant breeding, for both selection based on specific traits or on yield (Yan and Hunt 1998; IRRI 1997)

Apparently, good progress is being made in developing tolerant varieties for coastal Mekong Delta. A participatory approach involving mother trials on station and on farmer's fields, together with baby trials using farmers preferred varieties selected from mother trials and managed by farmers also seems very effective in Vietnam. The study shows that the released varieties were fairly stable across submergence and in stagnant affected rice areas. Several promising breeding lines have been selected and are being promoted for release as national varieties such as OM4900, OM6161, OM6162

Table 6. Yield trial at 5 sites in 2011-2012 WS (ton/ha)

Designation	Vi Thuy	Thoi Tan	Truong Xuan	Tri Ton	Thoai Son	Average (ton/ha)
OM4900	9.77	5.60	6.80	7.45	6.93	**7.31**
OM10041	8.67	6.07	7.20	7.50	7.60	**7.41**
OM7347	9.80	6.20	6.70	8.25	8.70	**7.93**
OM8928	8.40	5.67	7.27	10.10	10.26	**8.34**
OM8108	8.57	5.53	6.67	8.00	8.37	**7.43**
OM70L	7.07	5.00	6.13	7.00	8.27	**6.69**
Av. Yield	**8.71**	**5.68**	**6.79**	**8.05**	**8.35**	
I_j	**1.19**	**-1.84**	**-0.72**	**0.53**	**0.84**	

Base on the GxE interaction, I_j index can be ordered from unfavorable to favorable conditions as followed: Thoi Tan < Truong Xuan < Tri Ton < Thoai Son < Vi Thuy with the index of -1.84 < -0.72 < 0.53 < 0.84 < 1.19, correspondingly. The variety OM70L had the lowest yield while OM8928 showed the highest of 8.34 ton/ha then OM7347 of 7.93 ton/ha. In Vi Thuy, OM4900, OM7347, OM10041, OM8108 exhibited their predominant high yielding (from 8.57 ton/ha to 9.8 ton/ha) and in Tri Ton, the varieties that gave high yield were OM7347, OM8928, OM8108. In figure 1, the environments divided into two clusters at the coefficient of 1.22. Cluster 1 included Thoi Tan and Truong Xuan, in which the grain yield was low. They can be considered as unfavourable environment. Cluster 2 included Vi Thuy, Tri Ton, Thoai Son, in which the grain yield was high so that they are considered as favourable environment.

The genotypes divided into two main clusters at the coefficient of 1.3.

Cluster A**:** included OM8928 with high yield of 8.34 ton/ha.

Cluster B could be divided into sub-clusters B1 and B2.

Table 7. The regression coefficient (b_i) and the stability parameters (s^2_{di}:) 2011-2012 WS

Designation	Yield (ton/ha)	b_i	s^2_{di}	R^2 (%)
OM4900	7.31	0.96	1.04	48
OM10041	7.41	0.67	0.08	18
OM7347	7.93	1.11	0.19	32
OM8928	8.34	1.28	1.42	51
OM8108	7.43	1.01	-0.03	0
OM70L	6.69	0.84	0.34	15

Note: b_i: Regression coefficient indicating the adaptibility, s^2_{di}: stability parameters

OM 10041, OM 70L adapted to unfavourable environments (b_i<1) and OM7347 exhibited its wide adaptability and very stable yield among different sites.

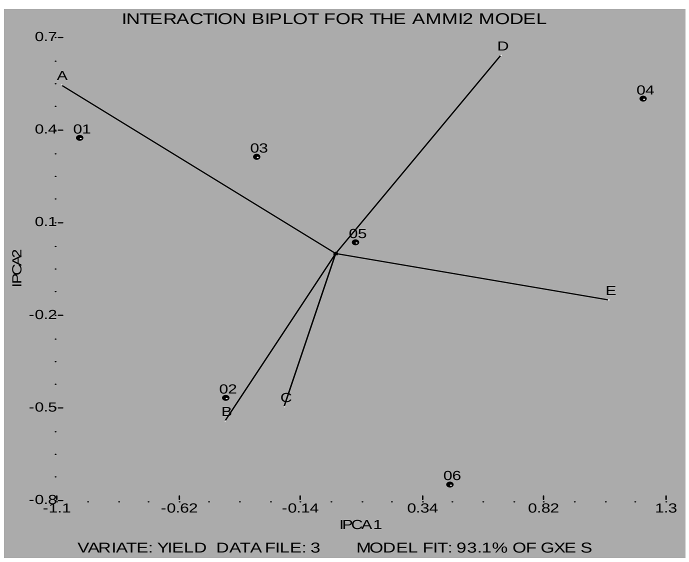

Figure 3. BIPLOT diagram express the stability of these genotypes at 5 locations with GxE 93.1%

Vithuy	Thoitan	TruongXuan	TriTon	ThoaiSon
A	B	C	D	E

OM4900	OM10041	OM7347	OM8928	OM8108	OM70L
1	2	3	4	5	6

Number 5 regarding to OM8108 is the best genotype due to its stability with its location at the diagram centre. Moreover, OM4900 is adapted to Vi Thuy, OM10041 to Thoi Tan, OM7347 to Vi Thuy and Tri Ton.

Table 13. ANOVA analysis of GxE interaction

Source of variance	Df	SS	MS	F	F table 0.05
Env. + (Genotype x Env.)	24	49.19	2.05	12.12*	2.06
Environment (linear)	1	1			
Genotype x Environment (Linear)	5	36.73	7.35	43.46*	2.57
Pool deviation	18	3.04	0.17		

Note: * signification at 5% level; It can be seen from the ANOVA table that genotype differed significantly

CONCLUSION

The grain yields of tested varieties are significantly different from the check OM4900 variety. Hau Giang 2, Can Tho 1 are considered as the highest yield genotypes. GxE interaction analysis shows that OM7347 exhibit wide adaptability and very stable yield among different sites. In 2011-2012 Winter-Spring, OM10041, OM8108 are the most stable genotypes.

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QUẢN LÝ NGUỒN GEN ĐỂ TĂNG NĂNG SUẤT LÚA TẠI CÁC VÙNG NGẬP VÀ NGẬP MỘT PHẦN Ở VÙNG ĐỒNG BẰNG SÔNG CỬU LONG

Báo cáo này tóm tắt các kết quả từ những năm đầu khảo nghiệm năng suất, các đặc tính nông học của những giống thích ứng với diều kiện ngập và ngập một phần, trong năm 2011-2012. Kết quả sơ bộ tập trung đánh giá 20 giống lúa trong khảo nghiệm MYT, vụ Đông Xuân 2011-2012, tại các điểm có điều kiện ngập và ngập một phần. Những khảo nghiệm PVS sau đó được thực hiện tại 5 điểm, với các dòng triển vọng của MYT trong vụ trước. PVS được thực hiện trong vụ Đông Xuân 2011-2012 tại An Giang, Hậu Giang và Cần Thơ. Đa số các giống có TGST 95-105 ngày. Tại mỗi điểm, nông dân cũng như các nhà khoa học cùng đánh giá các dòng tốt nhất, đặc biệt nhấn mạnh về phẩm chất, năng suất và tính kháng với rầy nâu và đạo ôn. Tiếp tục nghiên cứu tạo ra nhiều tổ hợp lai có bố mẹ là các giống lúa địa phương nhằm phát triển những giống mới phẩm chất gạo tốt, chịu ngập ở ĐBSCL.